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Characteristics of Red Algae Bioplastics/Latex Blends under Tension

M. Nizar Machmud*,1, Reza Fahmi2, Rohana Abdullah3,4, Coco Kokarkin5

1Laboratory of Materials Engineering, Department of Mechanical Engineering, Faculty of Engineering, University of Syiah Kuala, Jln. Tgk. Syech Abdurrauf No. 7, Darussalam, Banda Aceh, 23111 Indonesia
2Former undergraduate student at Department of Mechanical Engineering Faculty of Engineering, University of Syiah Kuala, Jln. Tgk. Syech Abdurrauf No. 7, Darussalam, Banda Aceh, 23111 Indonesia
3Department of Agrotechnology, Faculty of Agriculture, University of Bandung Raya, Jln. Cikutra No. 171 Bandung, 40124 Indonesia
4Post Graduate Student at Post Graduate School of Agriculture, University of Padjadjaran, Jl. Raya Bandung Sumedang Km. 21, Jatinangor, 45363 Indonesia
5Ministry of Marine Affairs and Fisheries Republic of Indonesia, Directorate General of Aquaculture, Brackishwater Aquaculture Development Centre Ujung Batee, Jln. Krueng Raya Km. 16, Ujung Batee, PO. BOX. 46, Banda Aceh, 23000 Indonesia
** Corresponding author: mnizar.machmud@gmail.com*

Abstract - Cassava, corn, sago and the other food crops have been commonly used as raw materials to produce green plastics. However, plastics produced from such crops cannot be tailored to fit a particular requirement due to their poor water resistance and mechanical properties. Nowadays, researchers are hence looking to get alternative raw materials from the other sustainable resources to produce plastics. Their recent published studies have reported that marine red algae, that has been already widely used as a raw material for producing biofuels, is one of the potential algae crops that can be turned into plastics. In this work, *Eucheuma Cottonii*, that is one of the red alga crops, was used as raw material to produce plastics by using a filtration technique. Selected latex of *Artocarpus altilis* and *Calostropis gigantea* was separately then blended with bioplastics derived from the red algae, to replace use of glycerol as plasticizer. Role of the glycerol and the selected latex on physical and mechanical properties of the red algae bioplastics obtained under a tensile test performed at room temperature are discussed. Tensile strength of some starch-based plastics collected from some recent references is also presented in this paper.
Key words - red algae, latex, tensile properties

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Introduction

Bioplastics or also called bio-based plastics are the terms usually used for plastics derived from renewable biomass resources [1]. Bioplastics, which were alternative to petroleum-based plastics in the past decades, had ever been actually of keen interest in the beginning of the 20th century when Henry Ford used corn and soybean oils to manufacture automotive parts [2-4]. Due to environmental awareness and sustainability issues, however, bioplastics have been just developed and re-consumed since the past 25 years [1,5]. Not only corn and soybean, the other food crops such as cassava, wheat, potato and sago, for examples, have also been nowadays turned into plastics to replace the use of petroleum-based plastics including improving quality of life worldwide [6-15]. The crops are food resources for human, however. Hence, continued turning the crops into plastics will interfere with human food supply, creating additional pressure on the world's diminishing food resources. To maintain normally consumption of the crops as raw materials for producing plastics, development of alternative sustainable raw materials has been one of strategies and plans to ensure the world's food security.

In recent years, a number of researchers have looked to get plastics from marine algae as an alternative raw material. Due to their rapid growing, up to 20% per day [16], easy cultivation and the incredible area of the sea, development of raw material from marine algae can ensure a sustainable raw material for producing plastics.

Together with starch-based plastics, plastics derived from marine algae are categorized as hydrocolloidal materials [17]. Without mixturing with other materials, such hydrocolloidal plastics generally could not be tailored to fit a particular requirement due to their poor water resistance and mechanical properties [17-23]. It was reported that, however, plastic film derived from agar red seaweed (*Rhodophyceae*) displayed better moisture barrier properties than cassava starch-based plastic film [18]. Mechanical properties of agar-hydrogenated vegetable oil emulsified plastic films were even comparable with some low-density polyethylene (LDPE) plastics [20,21]. Skurtys et al. [17], meanwhile, informed that carrageenans, which have been extracted from various red seaweeds (*Rhodophyceae*), presented high potentiality as film-forming material. A gelation mechanism in carrageenan film formation formed during moderate drying, leading to a three-dimensional network formed by polysaccharide doublehelices and to a solid film after solvent evaporation.

Glycerol is generally required for producing such hydrocolloidal plastics to overcome their brittleness [16]. A preliminary experimental study conducted to understand the role of glycerol on tensile properties of bioplastics derived from *Eucheuma cottonii*, a marine red algae species (*Rhodophyceae*), pointed out that strength of the bioplastics could not be significantly improved by use of glycerol and addition of glycerol even promoted deterioration of their tensile energy absorption.

Due to the complexities of their chemical compositions, tropical plants latex are selected for this work and then applied to improve ductility and strength of bioplastic materials. Latex of *Artocarpus altilis*, for example, is composed of aldehydes, ketones, aromatics, terpenes, carboxylic acid, fatty acids, ester and alcohol [24]. While latex of *Calostropis gigantea* consists of alkaloids, carbohydrate, glycosides, phenolic compounds/tannins, proteins, amino acids, flavanoids, saponins, sterols, acid compounds and resins [25]. In this present study, characteristics of red algae bioplastics derived from *Eucheuma cottonii* blended separately with latex of *Artocarpus altilis* and that of *Calostropis gigantea*, are evaluated under a tensile test performed at room temperature. Study on potential role of the tropical plants latex on mechanical properties of the red algae bioplastics is also discussed in this paper. Goal of this study, meanwhile, is to improve the tensile properties of red algae bioplastics with use of the selected latex.

Materials and Methods

Preparation of Bioplastics

Approximately fifty pounds of dried *Eucheuma cottonii*, as shown in Figure 1, which was collected from the West Coastal of Province of Aceh, Indonesia, was washed at first using water. They soaked then into water for 24h after washing. The soaked algae were chipped then into a size of approximately 2 cm. Boiling the algae chip were then performed up to 120°C by setting the water to the algae chip ratio at 7. This latter temperature was slowly further switched down and finally maintained at 80°C for 1 hour. Filtration was then conducted to separate small amount of solids from gels. The final filtration was repeatedly conducted after re-boiling the gels with the same method. This final filtrate with pure content of the algae gels was then poured over a frame (210 mm × 297 mm) and handmade sheet of bioplastics was further obtained after sun-dried for 3 days.

Preparation of Red Algae Bioplastics/Latex Blend

The handmade sheets of bioplastics which were prepared into strips were soaked into water for 24h by setting the water to the sheets ratio at 3. Gelation formation formed during soaking of the bioplastics was then boiled up to 120°C. This latter temperature was slowly further switched down and finally maintained at 80°C for 15 minutes. Gel formed at room temperature was then separately mixed with latex of *Artocarpus altilis* and *Calostropis gigantea* using a stationary blender consists of a blender jar with double blade at the bottom rotated by a motor at a certain constant speed. Pure red algae bioplastics without mixing with either latex or glycerol and a mixture mixed with glycerol (95% purity, 1.261 g/cm^3) were also prepared for reference materials. They were then poured over a frame (210 mm × 297 mm) and handmade sheets of them with a particular thickness were finally obtained after sun-dried for about 7 days. Density of the sheets was then measured manually after measuring the final thickness and weight of the sheets. Thickness of the sheets was measured using a portable digital thickness micrometer (Mitutoyo, Japan) while weight of the sheets was measured using digital laboratory balance (Sartorius P6, Germany).

Figure 1. Dried red algae (*Eucheuma cottonii*)

Tensile Test Method

A tensile test under a constant rate of 20 mm/min was performed at room temperature to obtain tensile properties of the bioplastics/latex blends such as elongation to failure, tensile ultimate load, tensile strength and tensile energy absorption. Such tensile test was also carried out for pure bioplastics and bioplastics mixed with glycerol. The handmade sheets of the red algae bioplastics were then further prepared to meet tensile test specimen requirements according to ASTM D 882-02. ASTM D 882-02 is a standard test method for tensile properties of thin plastic sheeting. Geometry and dimension of the tensile test specimen of the red algae bioplastics are illustrated in Figure 2.

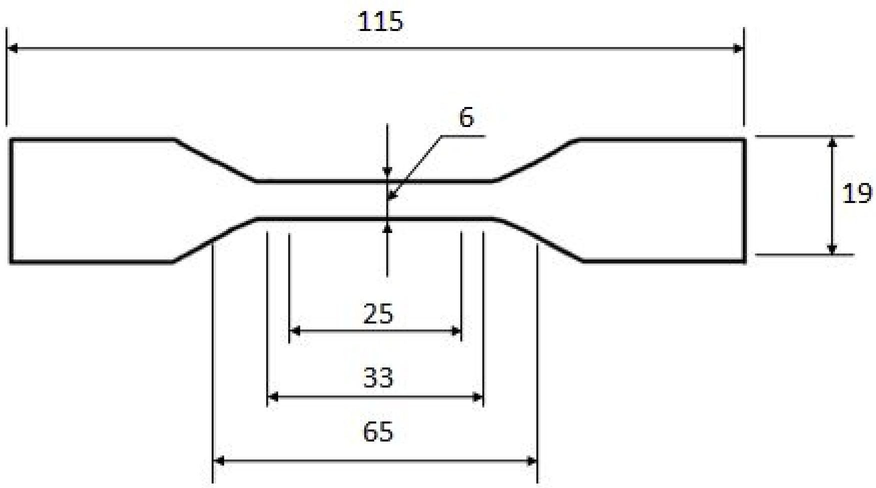

Figure 2. Geometry and dimension of tensile test specimen of the bioplastik (Unit in mm)

Results and Discussion

Role of Glycerol and the Selected Latex on Physical Properties of Red Algae Bioplastics

Handmade sheets of red algae bioplastics have been obtained. It was observed that a more transparent sheet was obtained by mixturing the bioplastics with glycerol. It reveals that glycerol played an important role in reducing the opacity degree of the red algae bioplastics. Observation to the final dried bioplastics showed that through thickness-linear shrinkage was significantly exhibited by all sheets made of the bioplastics. It was then measured and is presented in Table 1 and Table 2. As shown in Table 1 and Tabel 2, incorporation of glycerol and the selected latex separately with the red algae bioplastics did not significantly influence their linear shrinkage. Both Table 1 and Table 2 show that linear shrinkage of the red algae bioplastics with glicerol and those of the red algae bioplastics with the selected latex were comparable to those of pure red algae bioplastics. Differences of thickness and density exhibited by the red algae bioplastics incorporated with glycerol were induced by glycerol. This latter phenomenon reveals that use an amount of glycerol increases an amount of air in their mixtures. Latex of *Artocarpus altilis* and *Calostropis gigantea*, meanwhile, did not play a significant role on the physical properties of the red algae bioplastics.

Table 1. Physical properties of red algae bioplastics mixed with glycerol

Materials	**Glycerol** (%)	**Physical Properties**			
		Average Specimen Thickness‡ (mm)		**Average Linear Shrinkage*** (%)	**Average Bulk Density** (g/cm³)
Bioplastics√ (*Euchema Cottonii*)	0	T1	0,170	96.22	1,55
		T2	0,160	98.80	1,48
	15	T1	0,115	97.70	1,60
		T2	0,125	97.92	1,26

√ Prepared without latex.
‡ Final thickness in dried condition. T1 and T2 are initial thicknesses designed in this study.
* Linear shrinkage through thickness.

Table 2. Physical properties of red algae bioplastics blended with latex

Materials	**Latex** (%)	**Latex Material^**	**Physical Properties**			
			Average Specimen Thickness‡ (mm)		**Average Linear Shrinkage*** (%)	**Average Bulk Density** (g/cm³)
Bioplastics√ (*Euchema Cottonii*)	15	L1	T1	0,155	96.56	1,42
			T2	0.150	97.00	1,42
		L2	T1	0,165	96.33	1,45
			T2	0,155	96.90	1,57

√ Prepared without glycerol.
^ L1 is latex from *Artocarpus altilis* and L2 is latex from *Calostropis gigantea*.
‡ Final thickness in dried condition. T1 and T2 are initial thicknesses designed in this study.
* Linear shrinkage through thickness.

Handmade Specimen of Red Algae Bioplastics/Latex Blends

The handmade specimens of the red algae bioplastics/latex blends are shown in Figure 3. Figure 3(a) and Figure 3(b), meanwhile, show the specimens of the red algae bioplastics blended with latex of *Artocarpus altilis* (15% wt) and those of the red algae bioplastics blended with latex of *Calostropis gigantea* (15% wt), respectively.

The reference specimen made of pure red algae bioplastics and red algae bioplastics with glycerol (15% wt) are presented in Figure 4(a) and Figure 4(b), respectively. These reference specimens are further prepared for representing role of glycerol and the selected latex on tensile properties of red algae bioplastics.

Figure 3. A set of specimens made of red algae bioplastics blended with latex

Figure 4. A set of reference specimens of red algae bioplastics without glycerol (a) and with glycerol (b)

Tensile Test Results

Tensile test results such as elongation to failure, tensile ultimate load, tensile strength and tensile energy absorption are respectively presented in Figures 5, 6, 7 and 8. The tensile test results show that incorporating the red algae bioplastics with glycerol did not improved their ductility and the use of glycerol even reduced their tensile strength and energy absorption. In vise versa, however, although blending the red algae bioplastics with the tropical plants latex relatively reduced their ductility, use of the selected latex relatively improved their tensile strength and energy absorption. Figure 7, meanwhile, shows that tensile strength of the red algae bioplastics blended with latex of *Artocarpus altilis* was comparable with that of the red algae bioplastics blended with latex of *Calostropis gigantea*. As still shown in Figure 7, tensile strength of these latter materials, as expected, was even more superior to the others. It is most likely contributed by the complexities of chemical compositions in the selected latex. The maximum tensile strength of the red algae bioplastics blended with the latex materials is still better than those of starch-based plastics. Tensile strength of some starch-based plastics collected from some recent references is presented in Table 3.

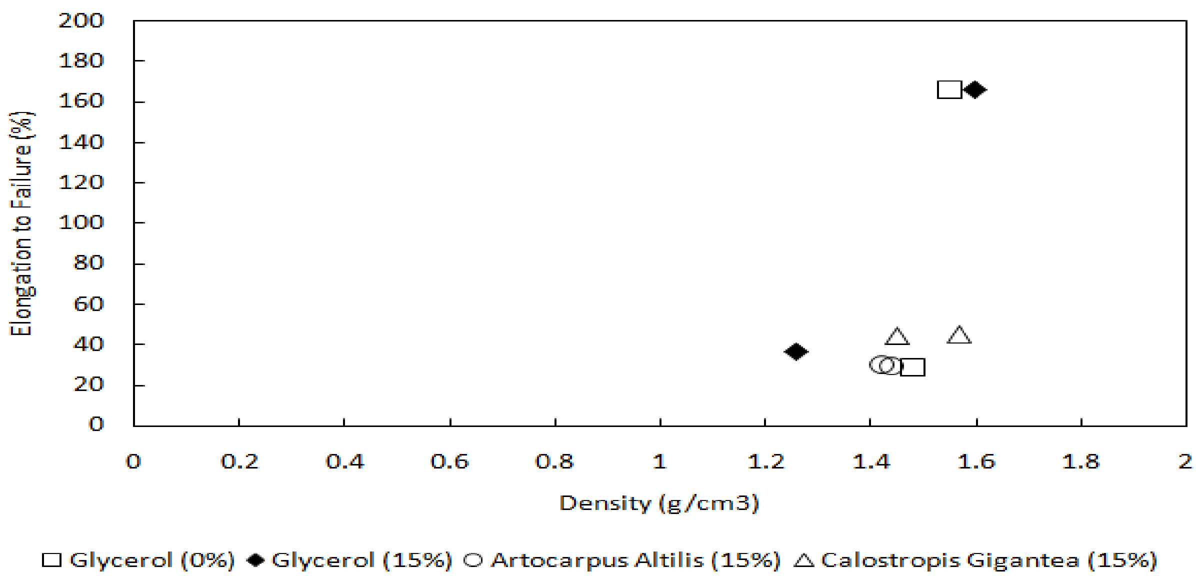

Figure 5. Density-based elongation to failure of red algae bioplastics

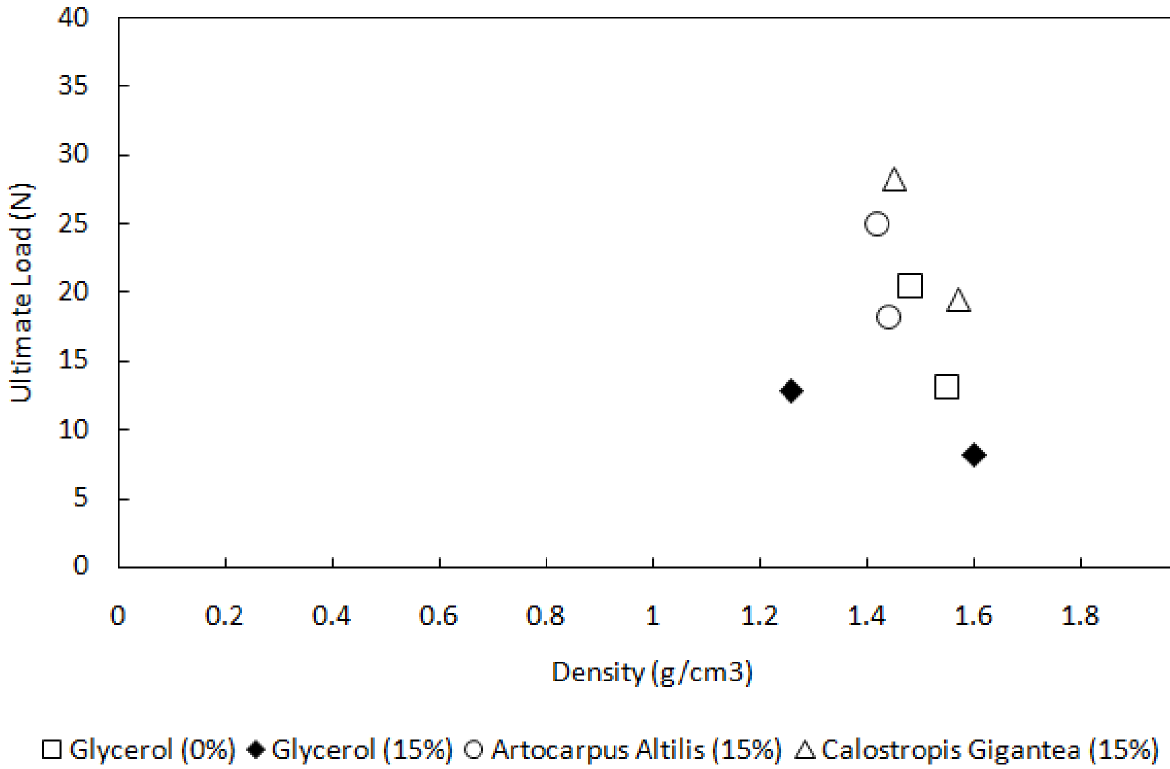

Figure 6. Density-based ultimate load of red algae bioplastics

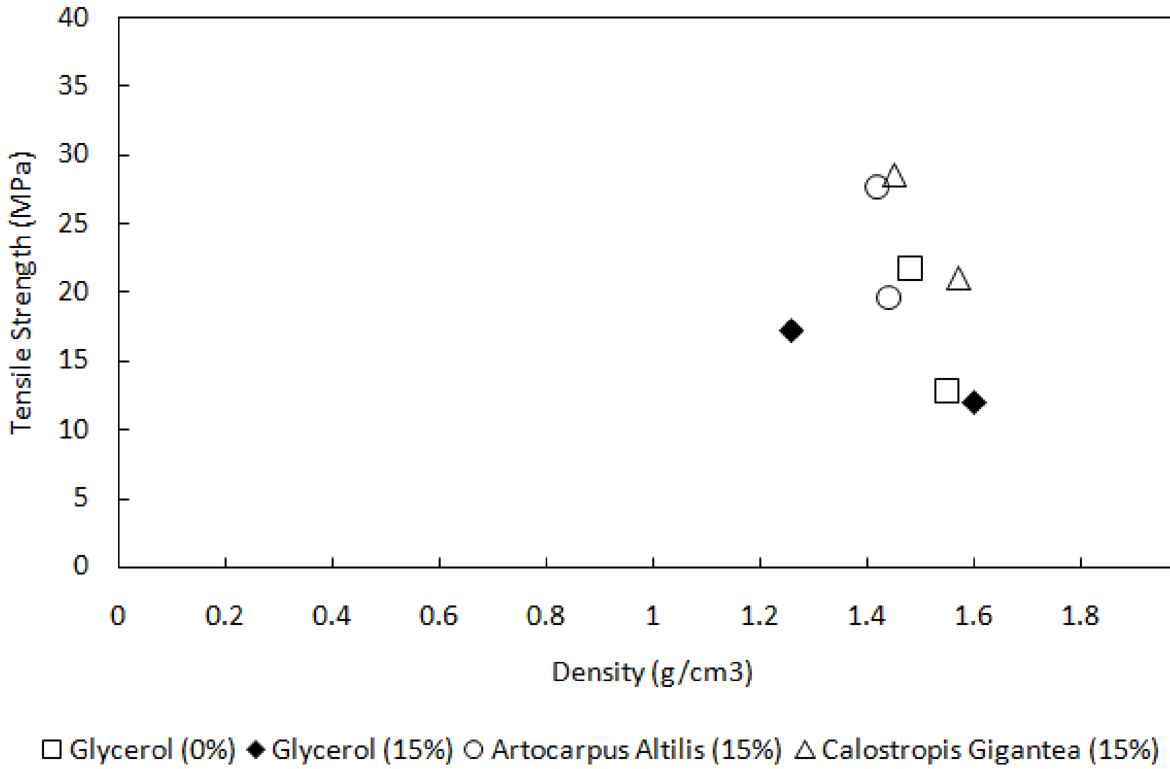

Figure 7. Density-based tensile strength of red algae bioplastics

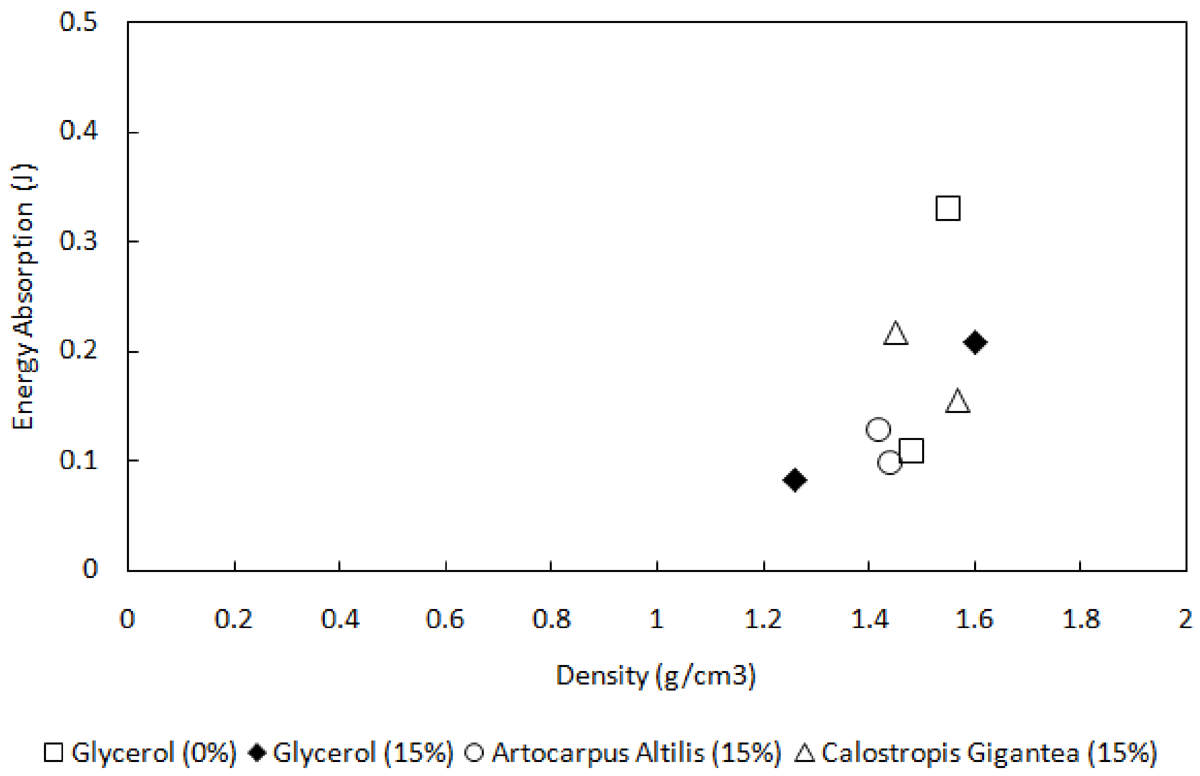

Figure 8. Density-based tensile energy absorption of red algae bioplastics

Table 3. Tensile properties of some starch-based plastics

Mechanical Properties	Elongation to Failure (%)	Tensile Strength (MPa)	Energy Absorption (J)
Ahmad et al. (2012)	-	24.766	-
Agustin et al. (2013)	-	15.6	-
Khan (2010)	-	18.22	-

Conclusions

Study on characteristics of red algae bioplastics derived from *Eucheuma cottonii* under tension which includes study of potential role of the tropical plants latex on physical and mechanical properties of the red algae bioplastics have been done. Roles of glycerol on the physical and mechanical properties of the red algae bioplastics were also studied. From physical properties of the red algae bioplastics, it was revealed that glycerol determined their degree of opacity and use of an amount of glycerol increased an amount of air in their mixtures which led to a decrease of thickness and density of the bioplatics. Latex of *Artocarpus altilis* and *Calostropis gigantea*, meanwhile, did not play a significant role on the physical properties of the red algae bioplastics. Evaluation work on the mechanical properties of the red algae bioplastics carried out under a tensile test performed at room temperature pointed out that incorporating the red algae bioplastics with glycerol did not improve their ductility and glycerol even contributed in reducing their tensile strength and energy absorption. In vise versa, however, although blending the red algae bioplastics with the tropical plants latex reduced their ductility, use of the selected latex relatively improved their tensile strength and energy absorption. Due to the complexities of chemical composition in the selected latex, tensile strength of the red algae bioplastics blended with the selected latex was more superior to the others and even to that of starch-based plastics. Blending with the tropical plants latex is hence recommended for the red algae bioplastics so that they could be tailored to fit any particular requirements in many applications of bioplastics.

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References

[1] Avérous, L., Pollet, E. eds. (2012). *Environmental Silicate Nano-Biocomposites*, Green Energy and Technology. Biodegradable Polymers, Springer-Verlag, London.

[2] Bioplastics Council. (2012). Bioplastics Industry Overview Guide, *Executive Summary Report*, The Society of the Plastics Industry, Inc.

[3] Andresen, C., Demuth, C., Lange, A., Stoick, P., Pruszko, R. (2012). Biobased Automobile Parts Investigation, *A Report Developed for*

the USDA Office of Energy Policy and New Uses, Iowa State University.

[4] Dell, K. (May 3, 2010). *The Promise and Pitfalls of Bioplastic* URL http://www.time.com/time/magazine/article/0,9171,1983894,00.html.

[5] Sugih. A. K. (2008). Synthesis and Starch Based Biomaterials. *PhD Thesis*, Mathematics and Natural Sciences, University of Groningen.

[6] Barker, M., Safford, R., Burgner, S., Edwards, C. (2009). *Industrial Uses for Crops: Bioplastics* URL http://www.hgca.com/publications/documents/Bioplastics_web28409.pdf.

[7] Sugino, T. (2003). Biodegradable Plastics from Crops: Implications from New Project in Japan. *CGPRT Flash*, 1(4).

[8] Sriroth, K., Sangseethong, K. (2006). Biodegradable Plastics from Cassava Starch. *Acta Horticulturae*, 703: 145-151.

[9] Petnamsin, C., Termvejsayanon, N., Sriroth, K. (2000). Effect of Particle Size on Physical Properties and Biodegradability of Cassava Starch/Polymer Blend. *Kasetsart J. (Nat. Sci.)*, 34: 254-261.

[10] Lim, J. K., Fujio, Y. (1989). DSC Thermogram and X-Ray Diffractometry of Bioplastics Prepared from Wheat Starch and Wheat Gluten. *Journal of the Faculty of Agriculture, Kyushu University*, 33(3/4): 195-201.

[11] Lim, J. K., Hayashi, N., Matsuo, H., Hayakawa, I., Fujio, Y. (1993). Plasticization of Wheat Starch-Gluten Mixture under an Elevated Temperature. *Journal of the Faculty of Agriculture, Kyushu University*, 37(3/4): 307-313.

[12] Rasheed, F. (2011). Production of Sustainable Bioplastic Materials from Wheat Gluten Proteins. *Introductory Paper at the Faculty of Landscape Planning, Horticulture and Agricultural Science*, The Swedish University of Agricultural Sciences.

[13] Talja, R. A. (2007). Preparation and Characterization of Potato Starch Films Plasticized with Polyols. *PhD Dissertation*, Department of Food Technology, University of Helsinki.

[14] Ahmad, Z., Anuar, H., Yusof, Y. (2011). The Study of Biodegradable Thermoplastics Sago Starch. *Key Engineering Materials*, 471-472: 397-402.

[15] Ahmad Z., Yusof, Y., Anuar, H. and Muhaimin, R. M. K. (2012). The effect of Water and Citric Acid on Sago Starch Bio-Plastics. *International Food Research Journal*, 19(2): 715-719.

[16] Machmud, M. N., Fadi, F., Fuadi, Z., Kokarkin, C. (2013). Alternative Fiber Source from Gracilaria Sp. and Eucheuma Cottonii for Papermaking. In *Proceeding of the 7th International Conference of Chemical Engineering on Science and Application*, Banda Aceh, Indonesia

[17] Hollingworth, C. S. ed. (2010). *Food Hydrocolloids: Characteristics, Properties and Structures*, Food Science and Technology. Food Hydrocolloid Edible Films and Coatings, Nova Science Publishers, Inc., New York.

[18] Phan The, D., Debeaufort, F., Luu, D., Voilley, A. (2005). Functional Properties of Edible Agar-based and Starch-based Films for Food Quality Preservation. *Journal of Agricultural and Food Chemistry*, 53(4): 973-981.

[19] Pomdage, W., Prachayawarakorn, J. (2012). Properties of Thermoplastic Cassava Starch/Low-Density Polyethylene Blend Modified by Carrageenan. In *Proceeding 38th Congress on Science and Technology of Thailand*, E_E0027 1-6. Chiang Mai, Thailand: The Science Society of Thailand.

[20] Debeaufort, F., Voilley, A. (2007). Effect of Surfactants and Drying Rate on Barrier Properties of Emulsified Edible Films. *International Journal of Food Science & Technology*, 30(2): 183-190.

[21] Phan The, D., Debeaufort, F., Voilley, A., Luu, D. (2009). Influence of Hydrocolloid Nature on the Structure and Functional Properties of Emulsified Edible Films. *Food Hydrocolloid*, 23(3): 691-699.

[22] Karbowiak, T., Debeaufort, F., Champion, D., Voilley, A. (2006). Water Barrier Properties at the Surface of Iota-Carrageenan-Based Edible Films. *Journal of Colloid and Interface Science*, 294(2): 400-410.

[23] Karbowiak, T., Debeaufort, F., Voilley, A. (2007). Influence of Thermal Process on Structure and Functional Properties of Emulsion-Based Edible Films. *Food Hydrocolloid*, 21(5): 879-888.

[24] Jones, A. M. P., Klun, J. A., Cantrel, C. L., Ragone, D., Chauhan, K. R., Brown, P. N., Murch, S.J. (2012). Isolation and Identification of Mosquito (*Aedes aegypti*) Biting Deterrent Fatty Acids from Male Inflorescences of Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg). *Journal of Agricultural and Food Chemistry*, 60(15): 3867-3873.

[25] Kumar, P. S., Suresh, E., Kalavathy, S. (2013). Review on a Potential Herb *Calotropis gigantea* (L.) R. Br. *Scholars Academic Journal of Pharmacy*, 2(2): 135-143.

[26] Agustin, M. B., Ahmmad, B., De Leon, E. R., Buenaobra, J. L., Salazar, J. R., Hirose, F. (2013). Cellulose Nanocrystals from Garlic Stalks as Reinforcing Filler for Bioplastics. *Polymer Composites*, 34(8): 1325-1332.

[27] Khan, S. (2010). Isolation Of Extracellular Proteins From Ophiostoma Ulmi And Their Effect On Tensile Properties Of Thermoplastic Starch, *Master Thesis*, Department of Cell and Systems Biology, University of Toronto.